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Comparison of impairment and restitution of hand function in a group of patients with total damage to the extensor pollicis longus and in a group of patients with damage to the flexor pollicis longus tendon after surgical treatment

Porównanie ubytku oraz odbudowy funkcji ręki w grupie pacjentów z całkowitym uszkodzeniem ścięgna prostownika długiego kciuka i w grupie z uszkodzeniem ścięgna zginacza długiego kciuka leczonych operacyjnie

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Key words
tendon injuries, dynamic splinting, rehabilitation

Abstract
Introduction: The thumb constitutes 40% of the whole hand function, and damage to the extensor pollicis longus (EPL) and/or the flexor pollicis longus (FPL) tendons of the thumb results in its significant limitation. The main factors contributing to damage of the EPL and/or FPL tendons are mechanical injuries - cuts and spontaneous ruptures.
Study aim: The aim of the study was to compare values of thumb and whole hand function loss and restoration as a result of the implemented physical therapy in patients with total damage to the EPL tendon with the values obtained by the study group 2 comprised of patients with damage to the FPL tendon.
Material and methods: The study involved 25 patients of the Specialized Hand Therapy Center in Krakow. 15 of them had ruptured continuity of the EPL tendon (study group 1), and 10 suffered damage to the FPL tendons (study group 2). The study included measurements of active motion of the thumb and wrist and superficial sensation. On the basis of these tests, functional impairment was measured using the methodology according to Swanson. The study included assessment of muscle strength in terms of global and precision grips using a dynamometer.
Results: Statistically significant functional improvement was noted for the thumb and whole hand as well as muscle strength in both groups. The values of functional loss differed between the two groups. The indicators of functional improvement were greater in patients with damage to the EPL tendon.
Conclusions: Functional physical therapy is an important factor determining the return of function in the thumb and whole hand after total damage to the EPL and FPL tendons.

Słowa kluczowe
urazy ścięgien, aparatowanie dynamiczne, rehabilitacja

Streszczenie
Wstęp: Kciuk stanowi o 40% funkcji całej ręki, a uszkodzenie ścięgna prostownika długiego kciuka (EPL) i/lub ścięgna zginacza długiego kciuka (FPL) prowadzi do jej znacznego ograniczenia. Głównymi czynnikami wpływającymi na uszkodzenie ścięgna EPL i/lub FPL są urazy mechaniczne – przecięcia i samoistne zerwania.

The individual division on this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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Cel badań: Celem pracy było porównanie wartości ubytku oraz odbudowy funkcji kciuka i całej ręki w efekcie wdrożonej fizjoterapii w grupie pacjentów z całkowitym uszkodzeniem ścięgna EPL z grupą kontrolną pacjentów z uszkodzeniem ścięgna FPL.
Materiał i metody: Badaniami objęto 25 pacjentów Specjalistycznego Ośrodka Rehabilitacji Ręki w Krakowie. U 15 z nich doszło do przerwania ciągłości ścięgna EPL (grupa badana 1), a u 10 uszkodzeniu uległo ścięgno FPL (grupa badana 2). Przeprowadzone badania obejmowały pomiary czynnej ruchomości kciuka i nadgarstka oraz czucia powierzchownego. Na podstawie tych badań obliczono ubytek funkcjonalny wg metodyki Swansona. Badania objęły również ocenę siły mięśniowej w zakresie ścisku globalnego i chwytów precyzyjnych przy użyciu dynamometru.
Wyniki: Wykazano istotną statystycznie poprawę funkcjonalną kciuka i całej ręki oraz siły mięśniowej w obu badanych grupach. Wartości ubytku funkcjonalnego różniły się pomiędzy badanymi grupami. Wskaźniki poprawy funkcji były większe w grupie pacjentów z uszkodzeniem ścięgna EPL.
Wnioski: Fizjoterapia funkcjonalna jest ważnym czynnikiem decydującym o powrocie funkcji kciuka i całej ręki po całkowitych uszkodzeniach ścięgien EPL i FPL.

INTRODUCTION

The thumb is the most important finger of the hand, because its correct function constitutes nearly 40% of its function[1-3]. As a result of the high use of the hands during everyday activities, the percentage of injuries, which they undergo, is very high. Frequent injuries are damage to the tendons, which are the second most common group of injuries within the hand[4-5]. Surgery is a doctrinal way of treating FPL and EPL tendon injuries in the form of reconstructing the ruptured tendon and specialist rehabilitation, which should be implemented after surgery as soon as possible[5-10]. In the case of the thumb, the most frequently damaged are the flexor pollicis longus (FPL) and the extensor pollicis longus (EPL) tendons. They most often occur as a result of cutting or rupture. Tendon rupture, often observed in the case of the FPL tendon, is a frequent bone fracture complication of the distal radius[11-14].

MATERIAL AND METHODS

The study included 32 patients of the Specialist Hand Rehabilitation Center in Krakow, who were admitted to the Center in the years 2012-2015. 7 of the subjects were excluded from the study because of lack of complete documentation (2 individuals from the EPP group and 5 from the FPL group). This was most frequently connected with the termination of rehabilitation and lack of a final examination. 15 people were admitted to the Center after suffering damage to the extensor pollicis longus tendon of the thumb (study group 1) and 10 individuals – with damage to the flexor pollicis longus tendon of the thumb (study group 2). The average age was 46 years in the EPL tendon injury group and 35 years in the group with FPL tendon injuries. The average time of rehabilitation was 10 weeks in each of the groups, during which 30 treatment sessions were performed (Table 1). With regard to the damage of the EPL tendon, it should be added that in 3 cases in the initial stage of treatment, the patients were misdiagnosed and an attempt at conservative treatment was undertaken as would be done in the case of partial damage and not total. In addition, 1 patient underwent surgery to transfer the ECRL to the EPL tendons nearly a year after the damage. Hence the high value of SD and the average time from the occurrence of injury to the time of performing surgical tendon reconstruction.

The majority of subjects, regardless of the analyzed group, suffered from a laceration of the tendon at work. In the case of the extensor of the thumb, the injury more often affected the dominant hand, as opposed to the flexor tendon - then the non-dominant limb usually was damaged. Most of the subjects in both groups underwent primary reconstruction of the damaged tendon (Table 2).

The research methods were standard goniometric measurements of active range of motion, superficial sensation, muscle strength – global grip at the level of the second (G2) and fourth (G4) grip width and precision grips - lateral (B), two- (2-pt) and three-point (3-pt). The measurements were performed according to standard metodology[9,10,15]. Exam 1 constituted the first measurement possible (usually after 4-5 weeks after surgery) and Exam 2 – the last measurement performed at the end of therapy at the Center.

Based on the results of range of motion and sensation measurements, we calculated the percentage loss of function of the wrist, thumb, and subsequently – fingers II-V and the whole hand, according to the methodology presented by Swanson[1].

When possible, rehabilitation started in the first days after the operation, which finds its justification in the reports by other authors[3,5-8,16]. The implemented therapy program was based on the results of the conducted diagnosis and was individually adjusted to each patient. The program comprised of exercises and treatments carried out at the Center and of a home program, and consisted mainly in:

1. Early stage (until the end of the fourth week after surgery):
   - dynamic hand splinting – FPL – Kleinert splint / EPL – reverse Kleinert splint;
   - exercises during splinting – FPL – Kleinert exercises, static progressive extension redression of the thumb / EPL – reverse Kleinert exercises;
   - tenodesis exercises;
   - "holding" exercises;
   - tendon gliding exercises;
   - antioedematous therapy;
   - scar therapy;
   - patient education;
   - laser therapy;
   - polarized light.
2. Late stage (from the beginning of the fifth week after surgery):
   - peg-board system exercises;

Table 1

Characteristics of evaluated persons	EPL	FPL
Number of evaluated persons	15	10
Number of women / men	9 / 6	3 / 7
Average age of evaluated persons (years)	46.1 ±8.85	35.2 ±15.4
Average time of rehabilitation (weeks)	10	10
Average number of therapeutic sessions	30	30
Average time from injury to surgery (days)	45.6 ±47.7	8.8 ±17.7

Table 2

Characteristics of injury in evaluated groups		EPL	FPL
Circumstances of tendon injury	Job	9	6
	House work	4	3
	Recreation	1	1
	Traffic accident	1	-
Mechanism of injury	Rupture	7	1
	Intersection	8	9
Side of injury	Dominant limb	9	3
	Non-dominant limb	6	7
Type of surgery	Primary reconstruction	11	8
	Muscle transfer	4	2
Place of living	City	10	8
	Countryside	5	2

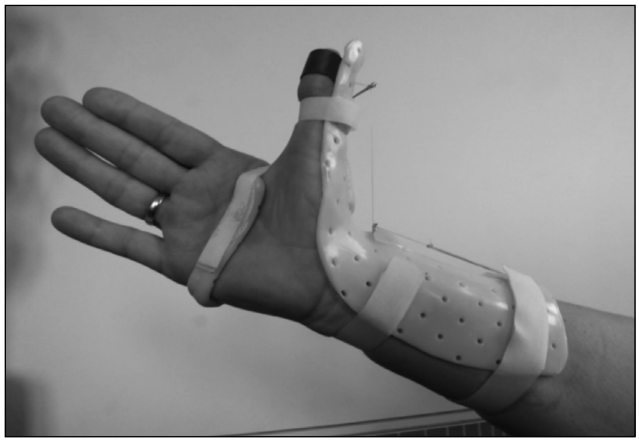

Figure 1
Kleinert reverse thumb splint

Figure 2
Kleinert thumb splint

- manual therapy;
- flextend system exercises;
- visual biofeedback using the Hercules kit;
- manual scar therapy;
- vacuum scar mobilization (pneumatic / aqua);
- functional muscle stimulation;
- iontophoresis;
- laser therapy.

The results of the conducted research were statistically analyzed using EXCEL2010. Descriptive characteristics of the study groups were noted and the significance of differences between and within treatment groups was calculated using the Student's t test ($p<0.05$).

RESULTS

Exam 1 was carried out after approx. 4-5 weeks following reconstruction because of the risk of damaging the tendon. Exam 2 was performed at the end of treatment at the Center.

The test results showed improvement in function of the wrist in the

area of each of the analyzed movements - both in patients after flexor and extensor tendon injuries to the thumb. In the group of subjects after FPL tendon damage, the largest initial loss was found during extension and the smallest - during flexion of the wrist. In exam 2, extension still remained the most limited movement, although its improvement was the greatest as a result of the applied therapy. In the case of the damaged EPL tendon, the greatest loss in Exam 1 was recorded during ulnar deviation, and the smallest during radial deviation. In the final exam, the biggest percentage loss was found during the extension movement. In the group with damage to the FPL tendon, the only statistically significant difference was noted in ulnar deviation. In people with damage to the EPL tendon, statistical significance was found for ulnar and radial deviation movements (Table 3).

Analysis of the percentage loss of function in the metacarpophalangeal joint (CMCP) showed a significantly greater decrease in Exam 1 in patients with damage to the extensor pollicis longus tendon of the thumb. In this group of patients, we also noted the largest improvement at the end of rehabilitation, which was statistically significant. In the group with damaged flexor pollicis longus tendons of the thumb, the difference between Exams 1 and 2 was also statistically significant. In Exam 2, we recorded similar values of the CMCP joint function percentage loss in both groups (Table 4).

Analyzing the percentage loss values regarding MCP joint function (MCP) of the thumb, we found slightly higher values in Exam 1 in patients with damage to the EPL tendon. At the end of rehabilitation of these patients, we noticed slightly less functional losses, which resulted from much greater improvement of function in these patients. The differences between Exams 1 and 2 in these two groups were statistically significant (Table 5).

The percentage loss in function of the interphalangeal joint (IP) of the thumb also decreased significantly after treatment in both groups. A greater difference was found in patients with damage to the EPL tendon, and the values in Exam 2 were very similar in both cases (Table 6).

Analyzing the function loss of the whole thumb, it was found that in Exam 1, this loss was higher in patients after extensor pollicis longus tendon damage, and in Exam 2 - after flexor pollicis longus tendon injuries of the thumb. Therefore, a greater difference between the exams was in patients with damage to EPL. In both groups, the differences between Exams 1 and 2 proved to be statistically significant.

In the case of the function of the whole wrist, the initial and final values as well as the difference were similar in both groups.

Analysis of the percentage function loss of the whole hand showed a similar dependence, as in the case of the thumb (Table 7).

Global grip strength of the operated hand was slightly smaller in Exam 1 in the case of damage to the FPL according to the G2 grip assessment. Values for the G4 grip were very similar to each other. At the end of therapy, muscle strength in the patients with damage to the EPL tendon was slightly higher, and the differences between Exams 1 and 2 in the two groups were statistically significant.

In the case of precision grip strength, the patients after damage to the flexor pollicis longus tendon of the thumb obtained lower values both in Exams 1 and 2. A statistically significant difference in the results of these measurements was found in both groups only in the case of lateral grip strength (Table 8).

DISCUSSION

Tendon injuries are a common and difficult challenge faced by many physiotherapists. Improper treatment can result in, for example, deformities, limited range of motion, which in turn, can lead to loss of function, and the surgical "correction" of these complications is difficult and expensive[7,16]. According to Howell and Peck[7], the introduction of early movement improves healing and reduces the risk of complications, and the selection of the postoperative splinting alternative and the proper exercise program are just as important as the surgical technique. Similar conclusions can be found in reports by Hsiao et al.[5] and Talsmy et al.[8]. An early and properly selected physiotherapy program is also a very important procedural aspect following muscle transfer surgery. This solution is used in case of failure during primary reconstruction of the damaged tendon or when, for various reasons, the primary anastomosis is impossible to perform[6,17,18,19,20]. A very important element in the rehabilitation period after tendon damage is also appropriate patient education regarding indicated exercise therapy, scar tissue therapy, splint usage, and furthermore, the performance of everyday activities which allow for the improvement of tendon healing conditions and minimize the risk of damaging the reconstructed tendon[21,22].

Many authors report the results of treatment of patients after tendon injuries[23-30], however, the difficulty of comparing results arises from the fact of presenting different methods of surgical treatment, the lack of standard protocols for rehabilitation, presenting the authors' own rehabilitation programs, using different research methods and non-uniform methods of presenting the final effects.

However, in the literature, there are no comparisons of the final treatment results of patients with various tendon injuries, showing the dynamics of changes occurring in the process of therapy and differences in the achieved final results. Most frequently, we encounter statements related to the use of various therapeutic programs, or the consequences of damage to the tendon within the different areas of trauma

The aim of our study was to compare the loss and restoration of hand function in two groups of patients after total damage to the extensor and flexor pollicis longus of the thumb. The results showed differences both in initial and final loss of functions and functional restoration progression.

Table 3

Percentage of wrist function impairment calculated using Swanson methodology [%]					
Wrist		**Extension**	**Flexion**	**Radial deviation**	**Ulnar deviation**
FPL	**exam 1**	5.15	1.43	2.29	4.14
	exam 2	0.5	0	0	0.34
	difference	4.65	1.43	2.29	**3.80**
	p	=0.11	=0.18	=0.08	**<0.05**
EPL	**exam 1**	4.17	3.50	3.33	5.00
	exam 2	1.00	0.00	0.00	0.17
	difference	3.17	3.50	**3.33**	**4.83**
	p	0.07	0.06	<**0.05**	**<0.05**
Wrist FPL/EPL	**exam 1**	*p*=0.111348	*p*=0.181609	*p*=0.087344	*p*=**0.043897**
	exam 2	*p*=0.292285	-	-	*p*=0.332126
	difference	*p*=0.334038	*p*=0.2951	*p*=0.144617	*p*=0.452842

* statistically significant results in bold

Table 4

Percentage of carpometacarpal articulation (CMCP) function impairment calculated using Swanson's methodology [%]				
Thumb		**CMCP**	**Adduction**	**Opposition**
FPL	**exam 1**	32.57	16.14	16.43
	exam 2	15.83	7.67	8.17
	difference	**16.74**	**8.48**	**8.26**
	p	**<0.05**	**<0.05**	**<0.05**
EPL	**exam 1**	54.00	27.29	26.71
	exam 2	16.14	8.43	7.71
	difference	**37.86**	**18.86**	**19.00**
	p	**<0.05**	**<0.05**	**<0.05**
Thumb FPL/EPL	**exam 1**	*p*=**0.000865**	*p*=**0.010401**	*p*=**0.003101**
	exam 2	*p*=0.46	*p*=0.31	*p*=0.42
	difference	p=**0.003178**	*p*=**0.03406**	*p*=**0.020848**

* statistically significant results in bold

Table 5

Percentage of metacarpea articulation (MCP) function impairment calculated using Swanson's methodology [%]				
Thumb		**MCP**	**Extension**	**Flexion**
FPL	**exam 1**	26.43	5.43	21.00
	exam 2	10.00	1.33	8.67
	difference	**16.43**	4.10	**12.33**
	p	**<0.05**	=0.18	**<0.05**
EPL	**exam 1**	33.14	3.86	29.29
	exam 2	6.00	0.00	6.00
	difference	**27.14**	**3.86**	**23.29**
	p	**<0.05**	**<0.05**	**<0.05**
Thumb FPL/EPL	**exam 1**	*p*=**0.018906**	*p*=0.181609	*p*=**0.011763**
	exam 2	*p*=0.28	*p*=0.15	*p*=0.35
	difference	*p*=**0.04895**	*p*=0.361309	*p*=**0.080086**

* statistically significant results in bold

Table 6

Percentage of interphalangeal articulation (IP) function impairment calculated using Swanson's methodology [%]				
Thumb		**IP**	**Extension**	**Flexion**
FPL	**exam 1**	22.71	6.71	16.00
	exam 2	15.00	4.00	11.00
	difference	**7.71**	2.71	**5.00**
	p	**<0.05**	=0.9	**<0.05**
EPL	**exam 1**	20.71	5.86	14.86
	exam 2	7.57	0.43	7.14
	difference	**13.14**	**5.43**	**7.71**
	p	**<0.05**	**<0.05**	**<0.05**
Thumb FPL/EPL	**exam 1**	*p*=0.06	*p*=0.097697	*p*=0.09
	exam 2	***p*=0.05**	***p*=0.05**	*p*=0.19
	difference	***p*=0.02887**	***p*=0.041844**	*p*=0.251653

* statistically significant results in bold

Table 7

Percentage of thumb, wrist and whole hand function impairment calculated using Swanson's methodology [%]				
Total		**Thumb**	**Wrist**	**Hand**
FPL	**exam 1**	22.91	6.53	11.22
	exam 2	11.45	0.45	6.01
	difference	**11.46**	6.08	**5.22**
	p	**<0.05**	=0.1	**<0.05**
EPL	**exam 1**	32.26	7.87	12.90
	exam 2	9.03	0.75	3.62
	difference	**23.23**	7.12	**9.28**
	p	**<0.05**	0.08	**<0.05**
Total FPL/EPL	**exam 1**	***p*=0.05**	*p*=0.101969	*p*=0.06
	exam 2	*p*=0.18	*p*=0.34	*p*=0.07
	difference	***p*=0.000367**	*p*=0.470336	***p*=0.008835**

* statistically significant results in bold

Table 8

Strength of operated hand [kg]						
Strength		**G2**	**G4**	**B**	**2-pt.**	**3-pt.**
FPL	**exam 1**	15.30	14.00	2.25	3.00	3.25
	exam 2	27.60	25.80	5.75	5.25	5.25
	difference	**12.30**	**11.80**	**3.50**	2.25	2.00
	p	**<0.05**	**<0.05**	**<0.05**	=0.14	=0.15
EPL	**exam 1**	17.17	13.67	5.40	4.40	5.40
	exam 2	31.83	26.67	8.50	6.83	7.50
	difference	**14.66**	**13.00**	**3.10**	2.43	2.10
	p	**<0.05**	**<0.05**	**<0.05**	0.12	0.17
FPL/EPL	**exam 1**	*p*=0.41	*p*=0.47	*p*=0.06	*p*=0.23	*p*=0.17
	exam 2	*p*=0.36	*p*=0.45	*p*=0.16	*p*=0.22	*p*=0.21
	difference	*p*=0.39	*p*=0.32	*p*=0.47	*p*=0.38	*p*=0.4

* statistically significant results in bold

In both groups, the post-operative treatment was comparable. Following surgery, as soon as possible, we implemented the Kleinert dynamic splinting program in the case of damage to the flexor tendon and the reverse Kleinert splint after damage to the extensor. Simultaneously, a series of exercises were performed to improve tendon gliding and to maintain and increase range of motion. Great emphasis was placed on the mobilization of post-trauma and surgical scars. Along with the progression of the results, progress in therapy and healing, and the increase in strength of the fixed tendons to the tensile forces, we expanded the program by further exercises to increase strength, endurance and functionality of the hand. When necessary, depending on the indications and the patient's condition, treatments were implemented in the field of physical therapy. After the applied therapy, all analyzed parameters were improved, and in the vast majority of them, the differences between Exams 1 and 2 in both groups were statistically significant (the only exception being the movement of MCP and IP joint extension in the FPL group, for which no statistically significant differences were found).

Analyzing all the obtained results, it can be seen that greater percentage functional losses found during Exam 1 occurred more frequently in patients after injury to the extensor pollicis longus tendon of the thumb. This was true both in the case of CMCP, MCP joint function (with the exception of extension) and the whole thumb (these differences were statistically significant) as well as the hand and wrist. The percentage joint function loss was only higher for the IP tendon, although only slightly, and was not statistically significant in Exam 1 in patients after injury to the flexor pollicis longus tendon of the thumb (Tables 3-7). This situation may result from the fact that during the time of dynamic splinting after damage to the flexor tendons, the injured fingers were set in a bent position for a longer period, which is also a more functional position than extension. However, using the extended thumb setting, which takes place after damaging the EPL tendon, may result in greater restrictions on the movement of flexion, which may, in turn, contribute to reduced functional capabilities.

In Exam 2, greater percentage function losses were more frequently related to the patients from the control group, i.e. after FPL tendon injury. Only in the case of the wrist and CMCP joint, along with various movements, was there an increase in functional loss observed in patients after EPL tendon damage. In this exam, statistically significant differences between the groups also occurred less frequently. They only took place in the case of the IP joint as a whole and during its performance of the extension movement. Chinchalkar[31] indicates various degrees of limitation in range of motion regarding various joints of the thumb after damage to tendons in the 1st section of extensors. In an attempt to present the results as relative values, and accepting the better results of patients following damage to the EPP as 100%, it was noted that the individuals with FPL damage obtained inferior results in the final exam. These results were worse by 49.5% in function of the whole IP joint, by 89.2% in its extension, by 35.1% in flexion and by 21.1% in relation to the function of the whole thumb and by 39.8% of the whole hand.

Greater initial loss in patients after damage to the EPL tendon, however, resulted in a greater difference between Exams 1 and 2 (Tables 3-7). This group of subjects almost always reached greater improvement during the applied treatment time (the differences were statistically significant), which in most cases, resulted in less functional loss percentages in the final study. In the case of the group of patients after suffering damage to the FPL tendon, greater functional improvement was noted only in the extension movement of the MCP joint. This situation may be due to the fact that the FPL tendon is more susceptible to secondary adhesions with the surrounding tissues.

Analysis of the results of the strength tests did not indicate statistically significant differences between the analyzed groups. In each of the measurements (with the exception of the global gripping strength measured at the fourth level of grip width) in both Exam 1 and 2, smaller strength values were obtained in patients after FPL tendon damage. The biggest differences in the final exam were reported in the case of precision grip strength. If we accept the strength obtained by patients from the EPP group as 100%, the FPL group acquired worse results in Exam 2 by 32.4% (B grip), by 23.1% (2-pt grip), by 30% (3-pt grip), by 13.3% (G2 grip) and by 3.3% (G4 grip). These results seem to be adequate to the past trauma. Both in the case of the lateral as well as the pinch grip, the two- and three-point grips, the flexor pollicis longus of thumb is a muscle which is directly involved in these functions. In the present study, another factor arguing for the smaller strength in patients with damaged FPL tendons is the more frequent damage to the non-dominant limb in this group. In the case of damage to the EPL tendon, the injuries usually concerned the dominant limb, which is usually stronger. Although, it should be emphasized that the return of strength is a long process and normal, daily functioning may even cause increased strength of the flexors, which are more active during daily household and professional activities. Based on Koul et al., Amirtharajah and Lattanza[30] state that the patients studied after damage to the extensor tendons do not obtain 90% of the opposite hand strength until 6 months after the injury. In the case of our patients, the average time of rehabilitation was 10 weeks. Analyzing the improvement in strength (excluding the lateral grip), similarly as in the case of functional losses, we observed increased strength restitution in the group with EPL damage.

CONCLUSIONS

1. In both of the analyzed groups, there was significant restoration in function of the thumb and the whole hand.
2. Reconstruction of thumb function in study group 1 is characterized

by twice higher level than in study group 2.
3. Damage to the flexor pollicis longus tendon of thumb results in smaller initial functional loss and less improvement in the function of the thumb and whole hand than damage to the extensor pollicis longus tendon of the thumb.
4. In Exam 2, we noted similar values of percentage loss in CMCP joint function.
5. The improvement of precision grip strength is slower than global grips, which indicates that the return of strength is a long process.

Conflict of interest: none

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